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# Concepts and tools from the learning sciences for linking research, teaching and practice around sustainability issues

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Though the research, teaching and civic missions of the modern university have often been considered distinct, changing notions of knowledge and practice suggest increased synergy. This paper develops insights stemming from the learning and developmental sciences on the nature of learning, its relation to practice, and how one can better design environments where learning can flourish. It explores ways the learning science literature could be much more effectively leveraged in study programs for sustainability. Using the proposed requisites of sustainable education programs provided in the typology of the first article of this special issue, we examine whether and how learning science theory and research can contribute to such ongoing efforts.

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Sustainability researchers and educators have viewed learning as an active and social process of transformation (Koenig, 2015). In this article, we explore how such a view can be enhanced by explication from theory and research in the learning and developmental sciences. Sustainability science research is both challenging and exciting because of the inter-disciplinary and transdisciplinary nature of knowledge building in this area. Sustainability scientists seek wisdom from a new generation to solve some of the most pressing environmental challenges humans face. This suggests the need for creating contexts where innovation can take place. A core question arises concerning how one frames research, teaching and civic missions of universities so as to maintain vibrant practices where novices are not simply viewed as apprentices growing into fixed communities, like a hand into a glove. In this article we discuss theory and research that highlight ways to conceptualize practice based learning as involving communities of learners where group variation is a driver of innovation. In addition to examining literature on what is known from the learning and developmental sciences about human learning, we also review theory and research about how to best design such environments to maximize their impact.

## Conceptualizing learning

Learning scientists can contribute to a more nuanced understanding of transformative learning and in particular ways to deepen sustainability science goals of building ecosystems that build the transformative social learning necessary for sustainable futures. Views of learning in the developmental and learning sciences discuss learning as a situated and social activity; where emphasis is placed on deep and lasting learning as opposed to surface learning, and where learning is viewed in terms of an extended developmental process that involves both active construction on the part of the individual, as well as input from the surrounding environment. To this extent, development and learning pathways are not biologically pre-determined but co-constructed. Three ways to elaborate on the view of learning and development in this article are presented here under the headers: first, learning is situated; second, learning is deep; and third, learning is a developmental process.

*Learning is situated*: conceptions of learning have moved increasingly away from unidirectional models of instructionism that focus on passive reception of knowledge. As noted by Koenig (2015) sustainability science researchers have increasingly focused on engaging students in what have been called high impact experiences [1]. The focus on experiential learning is a welcome shift away from instuctionist models of learning, but such work has yet to fully engage with the vast amount of theorizing and research in the developmental and learning sciences related to situated learning, a view that goes well beyond student engagement in authentic social activities.

According to situated views, learning not only takes place in and through participation but involves the adoption of practices, beliefs, and values of specific communities of practice. Communities of practice are fundamental spaces within which learning and practice take place (see [2,3••,4,5]). As practitioners, members of such communities do not only engage in activity but also come together

to develop a shared repertoire of resources. The resources may include shared experiences, stories, tools, and ways of addressing recurring problems. This cultural stock provides assets for new members as they enter and further the goals of the community. In this sense, the community comes to share a wide range of practices developed over a sustained period of time through ongoing efforts at working together on common and meaningful problems (see [5]). Participation 'refers not just to local events of engagement in certain activities with certain people, but to a more encompassing process of being active participants in the practices of social communities and constructing identities in relation to these communities' ([5], p. 4). This perspective has much to offer sustainability scientists.

*Learning is deep*: the instructional model of learning is based on a form of learning known in the learning sciences as surface learning. Students acquire through rote memorization a series of disconnected facts and procedures. One problem identified with surface learning is that students have difficulty accessing such superficially learned material in future learning. Learning scientists have noted that engagement with knowledge building is central to learning. But from this perspective, experience alone does not contribute to knowledge building and the formation of expertise. Learners must draw upon a significant knowledge base and familiarity with the tools available to the communities of practice and disciplines they engage with for deep learning to occur. Learning scientists have provided a large body of evidence that the formation of expertise involves a lot more than acquiring isolated facts and procedures, and draws upon practice with applying new knowledge in situations while learning and practicing how to use and modify new knowledge in authentic situations calling for unscripted solutions.

Developmental research has highlighted that learning is enhanced when learners are placed in situations where attention is placed on a prior knowledge and beliefs that learners bring to a given learning situation. Knowledge is constructed not only within interaction but based on and in relation to prior knowledge and beliefs. Such research has emphasized that experts pull from interactive situations very different knowledge than novices. And experts have also been shown to organize the knowledge they are acquiring in very different conceptual frameworks than novices. This suggests that a major aspect of learning depends on the construction of a richly structured knowledge base. Knowledge building takes place in interaction but is a complex developmental process that takes place over extended time most frequently by engaging in authentic or unscripted problems that call for the use of new learning (see [6,7,8••]).

*Learning is a developmental process*: developmental and learning science researchers have suggested at least three ways in which learning is a complex developmental process. First, students as learners enter learning at different phases of development; for instance, teenage learners and slightly older emerging adults have been noted to learn in significantly different ways [9,10]. Second, regardless of chronological age, expertise itself develops. Becoming a routine expert versus an adaptive expert involves different developmental trajectories. A routine expert is capable of repeating similar processes for ends that do not change, while an adaptive expert learns strategies for adapting for uncertain futures. Third, we know that because learning is situated, that learners are not fixed in their abilities and perform in different ways due to the environmental supports provided. We will take up each of these concepts in turn.

First, learners bring to the task of learning different capacities. For instance in a series of studies of high school and college learning of the same material (Introductory Psychology coursework), it has been found that high school and first year college students bring significant misconceptions to their studies which only after further time and experience change, when compared to the learning of upper level college students learning very similar material [10]. This work highlights the role that conceptual shifts play in learning; these conceptual shifts are reorganized across the college years as students are exposed to models and frameworks that challenge some of the knowledge frameworks they bring to their learning. One outcome of these findings highlights the important role instructors can play in conceptual shifts over developmental time by making their own theories and conceptualizations explicit and available for the students to learn from. Emphasis here is on understanding student understanding of material rather than what information teachers present. Learning is interpretive and meaning making a dynamic process [11].

Second, it is often thought that students first learn foundational material and then come to apply and revise prior learning to be an adaptive learner. Studies actually show that routine learning and adaptive learning follow distinct developmental trajectories. While routine and adaptive learners can both solve routine problems that they have become familiar with; what separates adaptive learners is their ability to solve problems that they have never experienced. One of the distinctive features is the extent to which adaptive learners have come to understand how to work in knowledge rich environments. One aspect that is characteristic of adaptive learners is their ability to draw on environmental supports through the use of the resources at their disposal [12]. This is central to work on sustainability science given the view that we are preparing students to contribute to uncertain futures and problems sustainability scientists cannot imagine. This suggests the importance of providing students with experiences where they come to know their strengths and

weaknesses and those of their team members so true distributive problem solving can take place. In addition, helping students reflect on how best to draw on or learn from the environments within which they participate to solve complex unscripted problems should become a central educational learning goal.

Third, developmental theory and research has highlighted the importance of looking at individual learning within broader ecosystems. Developmentalists have argued that at any given time, individuals perform differently when assessed on their own and when provided external support [13–15]. Known as the *zone of proximal development* (ZDP), Vygotskian theory has argued that learners are aided by mediational means that allow learning to first take place at the level of interaction with others, before individuals have internalized learning and show the capacity to function independently. Scaffolding by other individuals, especially those with more expertise — but sometimes through interactions with peers, can lead to abilities not originally witnessed when an individual is performing in a decontextualized and independent setting often used in testing. This also points out the variability of learning and development making assessment complex. Evaluators must give attention to the conditions under which performance is evaluated and recognize that only over longitudinal time, learners come to show increasing fluency and independence of learning. An example of how one can empirically study the ZDP and the complexity of learning can be found in Wertsch *et al.* [15].

Because learning is situated and draws on interactions with others, in designing learning environments, specific attention should be placed on the sorts of learning supports or scaffolds in place. Much of the work in the sustainability literature that talks about transformative learning looks at the general role others play in student learning. What could use more attention is careful study of whether and how scaffolding actually takes place. The learning science literature suggests that teachers and other experts often engage in specific rhetorical and mediated moves to assist student learning, in ways that are often tacit, but sometimes explicit. This involves employing specific pedagogical moves to allow learners to explicate their understanding of a situation to others or help them reflect on how others might view interactive settings in alternative ways. Michaels *et al.* [16] call these discursive patterns 'accountable talk' and suggest ways that accountable talk improves students' ability to participate not only in academic discourse, but also the practices more experienced others use in problem-based inquiry and practice. The use of accountable talk is not only central to knowledge work involved in asking questions, constructing models, providing evidence, and developing explanations but also such discourse patterns are central to democratic deliberations in civic arenas. Similarly Bielaczyc *et al.* [17] highlight specific talk moves such as a teacher asking students to articulate their emerging view of the solution suggesting the role of the instructor is less one of transmitting knowledge and more one of fostering a community of learners. The focus is not only on helping individual knowledge develop, but assuring that the talk moves of teachers open up dialogue to discuss multiple perspectives is key to learning and positioning students as active contributors of the learning community. This work need not be mediated through a teacher; learning scientists have argued that tools provide helpful representational means that assist learners to participate in the practices of a new community. Such pedagogical moves significantly scaffold interactions with learners early on, but over time students come to take on increasing agency for their participation. In this way teachers and experts facilitate learning through sequences of pedagogic moves that encourage student responsibility for new learning (see [16,17]).

## Vibrant practices: keeping participation dynamic

Much of the work on learning discussed in the learning and developmental science literature, while moving beyond instructionism models of education with their focus on participation, nevertheless might be taken to imagine learning as movement towards a fixed set of already established practices. This could suggest a view of learning as not simply of participation but growing into a preshaped practice community. In fact though this body of work, while recognizing members bring diverse experiences to the practice arena, nevertheless argues for transformative and open ended learning for all. To this extent, communities of practice and other knowledge building communities rest on the belief of ongoing transformative learning — where teachers, experts and others in the community are all learners drawing on the differences they bring. Such a view is consistent with the goals of sustainability science literature.

One of the key constructs used by learning and developmental scientists is that referred to as *legitimate peripheral participation*, a construct developed by Lave and Wenger [3••]. According to this view, learning is not just situated in practice (as a venue for learning or a crucial condition for learning), but rather participation is a constitutive element of practice. Peripheral participation, according to Lave and Wenger, is about 'gaining access to sources of understanding through growing involvement.' (p. 37). Legitimate peripheral participation is not a pedagogic form, but rather an analytic tool or framework for understanding learning and in particular, for understanding the growing involvement or ways of participation that learners embody. Lave and Wenger [3••] have studied a variety of learning communities and report that in all communities there is an initial phase where people join a community and learn at the periphery. The kinds of activities they are involved in, and the actions they perform are probably to

be less central to the community than others. Over time, through observation and recognizing their own distinctive contributions individuals play a more central role. The point here is that participation is more than just 'learning through doing' — there is a gradual process of entering into practice based communities where learning presupposes that newcomers are participating in legitimate practices that they are learning.

While recognizing legitimate peripheral participation as an early form of participatory learning, one of the central aspects of such communities of practice is that all members are authentically involved in future learning working on unscripted problems (see [3••,17]). Unlike apprenticeship models of learning, essential to open ended communities of practice is that both at an individual level and a collective community level the group believes they are working collectively to frame and solve important problems. Learning flourishes when diversity is enhanced and all participants can stand to learn from the diversity of expertise in a group.

Naturally this participatory structure is at odds with how most learning takes place in formal settings, especially in higher education where expert teachers work with novice students. One especially counter-intuitive example of the ways even novices can collectively learn, stems from a recent study of how a group of relative novices working with persistent uncertainty came to outperform others who were trained to apply abstract decontextualized knowledge based on experts in similar contexts (see [18]). This Special Issue offers many wonderful examples that challenge the assumption that experts simply pass on knowledge and practice to novices and instead suggest ways that experts from different domains come together to co-construct meaning and practice.

Crucial to the dynamic nature of these learning settings is the flexibility of these settings to change. Within a community of practice model, the actual behaviors and routines of these communities are open ended and always in flux as new members replace older ones, and as the needs of the community and the environment within which they function call for different relationships (see [19••]). Innovation actually happens when diverse communities are able to come in contact and learn in a community-of-communities approach, whereby new practices and knowledge is integrated across traditional boundaries. One finding of learning scientists focuses on the important ways the design of environments fosters settings where innovation can take place.

## Designing environments where learning and practice can flourish

In traditional models of learning an expert in a given area is said to be involved in transferring knowledge of a given area to a novice. The teacher is thought to have content in the head to transfer to the learner. But the 'sage on the stage model' with its clarity in how design of learning environments takes place, works poorly for the views of learning and practice discussed in this Special Issue. What are key design features for enhancing the kind of learning and practice outlined by the practice based approaches discussed here? It might be thought that one simply needs to bring together individuals who care deeply about authentic and unscripted problems and based on that co-location, learning will happen. It turns out there is little support for such a claim by learning scientists.

Developmental and learning science theorists and researchers have identified a set of design features that are crucial to environments where learning can flourish. One can neither expect these to develop out of top down processes, nor organically from bottom up experiences of a group of willing learners. Budwig [2] and Budwig *et al.* [20] refer to a third option, a process of *guided emergence*, namely where facilitation takes place in ways that do not determine but rather allow for the emergence of key features associated with optimal learning. Guided emergence emphasizes the role of leadership and instructors as one of designing environments that assist in the creation of new knowledge by others. What sort of guided emergence is useful? Three core features include assuring:

1. clarity in strategic context
2. contexts that allow formal and informal relationships to develop
3. tools and artifacts are documenting and assisting in the knowledge building, including mechanisms to capture the methods, stories, and documents that result from the work.

In this sense, the core educator is not transmitting but supporting the guidance and infrastructure of early phases of learning, encouraging ongoing work, and making sure the knowledge and practice coming out of the group is integrated into larger fabric of the organizations of which the knowledge building is a part.

Guided emergence can be tricky in that the tendency to micro-manage or problem solve is more natural than that of facilitating others to find their way. To this extent, tools and artifacts can be helpful. As noted above, human learning is often mediated by more experienced others often through language and other symbolic forms. Tools and artifacts can provide similar metacognitive guidance that leave room for unscripted solutions that are needed for real-world problems. For example, Bielaczyc and colleagues have designed scaffolding tools that highlight particular knowledge-building moves for practice and reflection as a means of supporting learners and others to come to a collective improvement of ideas. Similarly

Knowledge Forum is an e-workspace that supports the knowledge-building process for stakeholders, providing tools to encourage sharing and synthesizing of new ideas from diverse sources [21].

If tools and artifacts provide instructors with powerful mechanisms to enhance organic learning, reflection provides learners with a powerful tool for learning as well. The notion of reflective practice as central to human learning is not new (see [22–24]). Reflective practice can be implemented as a tool to not only monitor learning but also as a tool of continuous learning for the individual learner. Reflective practice goes beyond experience; deliberate reflection or reflection in action can lead to enhanced understanding through making the tacit more explicit by abstracting, synthesizing, and articulating the key lessons learned. Student assignments ideally are designed with possibilities for reflection in mind.

All of this suggests that experiences and real-world problem solving alone will not foster transformative learning. Rather, the 'wrap' around contextual learning — the design of the environment, the use of mediational means to support newcomers, and the reflections individuals make to synthesize learning are all central to the process.

## Conclusions

Sustainability science with its transformative view of social learning clearly shares much in common with what much of what has been put forth in developmental and learning science theory and research. Overlap exists in a movement away from static views of learning towards more dynamic and social processes. In addition, both sustainability researchers and developmental and learning scientists all embrace the notion that all participants are learners and that learning is an open ended system of continual creativity and innovation. And both groups embrace a view of learning where focus shifts from one of learning about to learning-in-work.

Having noted these overlaps there are some areas where work going on in the learning and developmental sciences can contribute to sustainability science work. Three broad ways to think further about connections between these areas include the following. First, learners bring to the task of learning different developmental capacities for knowledge building. Students new to college and university are beginning to reorganize conceptual frameworks about science and inquiry and this takes time. What they draw from early experiences with practice based learning communities will be different than those students and practitioners who have broader experience. To this extent learning is a developmental process experienced differently at different moments of the life span. How this plays into sustainability research is an open area of study and one that offers developmentalists a rich area of research.

Second, a key aspect of the more social transformative learning model is not simply the active engagement in activities, but the capacity for the learning to come to build new knowledge as well as values and identities in relation to that work. Learning goes well beyond doing. As learners acquire new ways of being, they simultaneously develop tools and methods to think and act on unscripted events. This capacity is central to the sort of learning that citizens will need in the 21st century.

Finally, the learning sciences provide sustainability researchers both a venue and a method for more deeply understanding the role of tools and mediational means in human learning. The range of solutions needed for complex problem solving related to sustainable futures is unscripted and provides a venue for learning scientists to learn much about unscripted learning. Until now, much of the literature has focused on disciplinary based learning or expertise associated with less open ended domains such as learning chess or what it means to become a midwife or a tailor. Simultaneously, sustainability scientists have yet to fully study the role that mediational tools and representational means can accelerate or otherwise assist in the kind of complex and innovative problem solving necessary for sustainable futures.

In closing, it also is important to realize that the social transformative view of learning put forward by sustainability researchers serves a larger end for universities. As pointed out by Ramaley [25], such work offers a platform that serves colleges and universities well to the extent that it imbues in students a spirit of responsibility. In addition, working on complex sustainability issues provides higher education an arena that offers a better bridge between the academy and the world beyond university gates, providing students with a platform to engage in integrative liberal learning that will be essential to the world they enter regardless of particular profession.

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